Prototype Parking Meter System – Phase 3

Status Report

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List of symbols and definitions

A

B

C **C++**
A high-level object-oriented programming language—the language used for the software in this project

Client
Metal kiosk which contains the user-interface (LCD display, printer, coin accepter and keypad) and provides administrative capabilities. All users interact with the client unit to pay for parking or to change settings in the parking system.

D **Dec04-02**
The senior design group responsible for the second phase of the project

DPS
Department of Public Safety, the division of Iowa State University responsible for monitoring parking on the campus

E – F – G – H – J – K

L **LCD**
Liquid crystal display, a low-power digital display that uses liquid crystal cells that change reflectivity in an applied electronic field

Linux
An open source operating system based on UNIX traditionally used for servers.

M **May04-02**
The senior design group responsible for the first phase of the project

Motherboard
For this project, it is a main circuit board of the embedded computer through which all signals are directed.

MySQL
MySQL is a fast-relational database manager. A database manager enables adding, retrieving, and processing information stored in a database. The relational aspect of MySQL means that data is stored in separate tables rather than one large table. Relations between each table can be established and information can be retrieved using structured query language (SQL).

N – O – P – Q

R **RAM**
Random-access memory, the primary working memory in a computer used for the temporary storage of programs and data and in which the data can be accessed directly and modified

S **SQL**
A standardized language that approximates the structure of natural English for obtaining information from databases

Server
One machine that contains the mySQL database for a given parking lot

Server Unit
A pair of servers with replicated databases and failsafe capabilities

T

U **USB**
Universal serial bus, a plug-and-play interface between a computer and peripheral devices, such as printers, modems, and keyboards

V

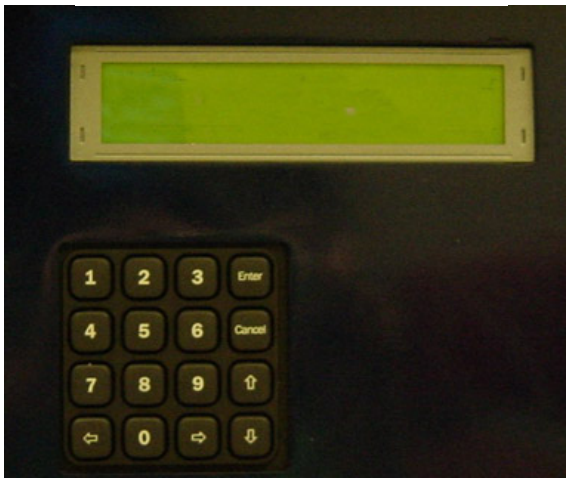
W **Window XP Embedded**
A compact and modular operating system provided by Microsoft Corporation that allows users to select the exact features and functionality of the OS required for the application or device—the operating system used for the client unit in this project

Wired Ethernet
A trademark for a system for exchanging messages between computers on a local area network using wired coaxial, fiber optic or twisted-pair cables

X – Y – Z

1. Executive Summary

Figure 1 – ATM-like interface



There are a number of reasons that a new parking meter system is needed. Currently, the university is planning the need for new public parking lots and the current parking meter systems are too expensive to maintain, not configurable enough, and don't allow for communications between individual units within the same lot. This project will address all three of these issues by implementing a complete system with a simple, ATM-like user interface.

Currently, the system is relatively inexpensive to manufacture, coming in at around $1,500. If you include man-hours, the system will cost only $15,000. The top of the line systems on the market out there weigh in at over $75,000 and do not have all the planned features that this project will implement. Even with a commercial market mark-up of 400%, the system will still be less expensive than other products.

Configuration considerations were also a major reason for beginning this project. Systems that are currently available on the market today do not have the necessary options to facilitate all the different dates (holidays, breaks, etc.) and rate schedules that have been implemented with this project. Additionally, the design of this parking meter system is expandable and another project team can add features in the future.

Finally, the need for individual units (henceforth referred to as clients or client units) to communicate, even though they may be at opposite ends of a parking lot or on different levels of a parking ramp was very important in the design considerations of this parking meter system. The system allows for customers to add time to the stall where their car is parked from any client unit in that lot, regardless of which client unit was originally used to pay. This communication also aids parking supervisors and administrators with managing the lot by allowing them to print off the unpaid stall list from any client unit instead of printing off a list from each unit (as it is with the current system.)

The system will accomplish many of the aforementioned features by implementing a client-server parking scheme. Throughout a parking lot, a number of client units will allow customers, administrators, and supervisors to perform various tasks, such as paying for and adding time to a stall (for customers), updating rate schedules, adjusting how many stalls are available in a particular lot, checking for parking violations (for supervisors/administrators) in addition to many other features. These clients will communicate with a centralized server unit that can either be located in a physically different location as the client units (such as in a building) or in an enclosure with one

of the client units (along with the LCD, coin accepter, printer, etc.) This server will store all the relevant data for a particular parking lot—all of the stall information (paid, unpaid, expirations, etc.), the rate structure, and all statistics for that lot.

As of this writing, the hardware has been completely integrated into the case and the software is also complete, however the testing of the hardware and software together is ongoing and is taking longer than expected. The testing process for the prototype unit is currently on the second full round— the first round produced many bugs that have been fixed but another is required to ensure that a given fix didn't necessarily break something else. The testing procedure will be fully described in a later section.

During and after testing, extensive documentation will be created to facilitate administrators and supervisors of the system in maintenance and operation of the units.

2. Acknowledgement

The project team would like to thank the following people for their time, ideas and financial contributions to the project: Doug Houghton of the Department of Public Safety, Iowa State University and May04-02, Dec04-02, Dec05-02 electrical / computer engineering senior design teams. The group would also like to acknowledge our project advisors, Dr. John W. Lamont, and Professor Ralph Patterson III for their advice and guidance with the project.

3. Problem Statement

Below is our General Problem Statement and Approach.

3.1 General Problem Statement

Availability of public parking on or near campus is a concern at Iowa State University. Because of this, several pay-for-parking lots have been installed on the Iowa State campus. With traditional parking meters, such as those seen throughout cities along downtown roads (among other places), one is needed for every parking spot. Currently, a few lots on campus use centralized units that are able to accept money and track multiple parking stalls. This setup provides advantages over the traditional parking meters, such as monitoring the entire lot and collecting money from fewer locations, however there are several problems with the current system. The current units lack the ability to communicate with one another. This means that when the lot is checked for offenders, each machine must be checked individually. Also, if a customer wishes to add time to a space they have already paid for, they must return to the same machine that they originally paid from. Finally, the lack of communication means that if one unit becomes disabled, all data stored in it becomes lost and/or inaccessible.

Another problem is the current system's units are very difficult to program. DPS has requested the ability to program in university holidays, as well as change the hourly

rates. The current units require that a specialist be flown in from a remote location do this, a process that is both expensive and time consuming.

3.2 General Solution Approach

The prototype solves this problem by providing an advanced and intuitive system to monitor the pay-for-parking lots. The prototype is similar to the system in current pay-for-parking lots implemented on the Iowa State University campus, but drastically improves upon them by increasing features and making it easier to manage for the supervisor. The new system will be more affordable and user-friendly, as well as easier to maintain.

The solution in development can be implemented with many client units—all of which will communicate with a central server. All client units in a parking lot will be able to communicate with one server unit per parking lot, allowing users of the lot to add time from any machine located at that lot. The new system will allow DPS parking enforcement officers to receive a printout of lot activity. In addition, the prototype will have a redundant server mechanism, which means that if a certain part of the server should fail, a second machine will seamlessly take over where the first one left off.

The new units will have a simple to use interface that will make it easier for customers parking in the lots to use the system as well as allow DPS to easily administer the system. Finally, the system will be implemented with standard computer hardware. This will make duplication easy and decrease the cost of construction and maintenance of the units.

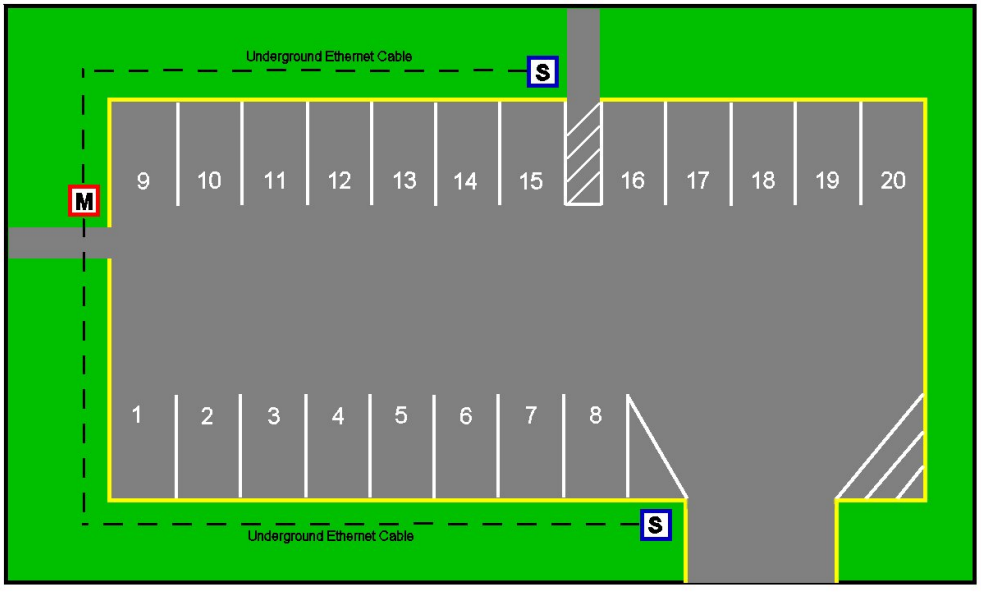


Figure 2 – Hypothetical Parking System Implementation

4. Operating Environment

The unit will be installed in an outdoor location on the campus of Iowa State University in Ames, IA. It must be able to withstand all the weather conditions present in this

location. The unit will be able to deal with both extremes of temperatures, as well as all forms of precipitation such as rain, snow, and hail.

The client unit will be used on a regular basis, often by users that may treat the unit roughly or by users that are not familiar with the system. Because of this, the unit must be durable and user-friendly, making the customer process as painless as possible.

Finally, because the unit will be located on a college campus, it must be sturdy, and resistant to any attempt at vandalism.

5. Intended Users

Three classes of users will use the system. The first class includes college students at Iowa State University, faculty and staff of Iowa State University, and visitors to the Iowa State Campus.

The second class of users is DPS parking enforcement personnel, who are referred to as administrators. They will need additional functionality in order to monitor the parking.

The third class of user is the supervisor, who is a permanent employee. This user will have access to all the features available to the administrator class, in addition to the ability to change settings of the system, such as the rates and schedules.

6. Intended Uses

The system will have three classes of users (see Section 5), each of which has different functions. The robustness of the system is too great to put a comprehensive list of all features, so below can be found a few examples of functions for each class of user.

- For the first class of users, customers that park in the lot, the system will:
    - Allow parking spaces to be paid for in various ways, such as by specifying an "end time" or by putting in a specific amount of money
    - Allow time to be added to a parking space from any client unit connected to the server unit, regardless of which client unit was originally used
    - Print a hard-copy receipt if the user desires
- For the second class of users, parking administrators, the system will:
    - Allow users to monitor paid and unpaid parking spots in the lot
    - Allow users to gather parking lot statistics
- In addition to the features above, for supervisors the system will:
    - Allow users to change hourly rates and a rate schedules
    - Allow users to set holidays and special events
    - Allow users to add and delete second and third class users

7. Assumptions

Below is a list of all the assumptions that the group are taking into account when designing the system.

- The lot size will be no more the 1000 spaces
- The units will not provide change
- AC power will be provided to the unit
- The units will only except nickels, dimes, and quarters as payment
- Iowa State University Facilities Department will install the system

8. Limitations

The system has a few functional requirements that must be taken into account when implementing the system. Below lists a few of the limitations that either the group set or that our customer had.

- The time to have the prototype completed is very limited
- The system must implement all the features of the current system
- The unit must withstand Iowa outdoor conditions
- The unit must be theft resistant
- The user interface needs to be compact and easy to use
- The system must allow for different rates, depending on the time of day, holidays, and break schedules
- The hardware unit must print receipt upon request
- The server unit must be completely redundant, i.e. if a certain aspect of the system should fail, another part of the server unit should immediately take over
- The unit must be able to run for 20 minutes or more if power goes out
- Users should be able to add time to their current remaining amount from any client unit in a lot
- The hardware must provide the current payment status of the lot for parking enforcement

9. Expected End Result and Other Deliverables

The end products for this project will be a fully functional client prototype, one server prototype (actually two server computers linked for redundancy), the multi-space parking meter system software (both client and server implementations), complete user documentation, and a detailed technical specification. These items are detailed below:

Client/server prototypes and multi-space parking meter system software

Figure 2 – Parking lot sign

This system will consist of one of more client units connected to a central server unit. The server unit may be in the same enclosure as a client unit located at the parking lot or in a nearby building so that managing parking lots can be done in many locations. The system will be capable of handling up to 1000 parking spaces. The server unit will store all of the parking lot information. The client units will retrieve this information and act as the interface from which parking time is purchased and administrators and supervisors can update pay rates, change parking schedules and/or manage a parking lot.

User Manual

The user manual will be a document detailing the operation of all the machines in a non-technical manner so that any user of the system will be able to understand it. The operations described in the manual will include monitoring occupancy, making rate changes, as well as other enforcement functions.

Technical Specification

The technical specification document will be a document describing the technical specifications of both the hardware and software running on the master and slave units. This document is not designed for common users, but instead is intended as a resource for future developers and maintainers of the system. The completed technical specification of the system will be delivered with the rest of the final system.

10. Previous Accomplishments

Below is our list of accomplishments for the project.

Fall 2003 - Spring 2004

In this timeframe the following was accomplished:

- Created complete problems definition which containing uses, assumptions, limitations, functional requirements, management procedures, and success evaluation criteria. This part is completely done and state on the project plan.
- Research hardware and software to meet the project functional requirements, robustness, has current availability and is within budget. All components have been selected within budget but some of the selected components have been changed in phase 2.

Spring 2004 – Fall 2004
In this timeframe the following was accomplished:

- Selected hardware and software for the project implementation. All components are collected and ready to build the prototype
- Completed project design with no design issue during implementation. The design is well completed and stated on the project plan
- Define functioning product that meet the design requirement, specification and client needs

Fall 2004 – Spring 2005
In this timeframe the following was accomplished:

- Completed user interface flowcharts
- Completed creation, customization and installation of Windows XP Embedded to the slave computer's storage device
- Completed the software classes and functional description
- Implemented software classes
- SQL database for master units was installed and configured
- Basic customer testing and bug fixing

11. Present Accomplishments

The following will be completed this semester:

- Completed software to run on the slave computer
- Modification of user interface for user friendliness
- Coin acceptor powered and connected
- Liquid crystal display powered and connected
- Thermal printer powered and connected
- Uninterruptible power supply purchased and installed
- Integration of the hardware and software as a prototype for testing, including master and slave components
- Software testing, bug analysis and removal
- System chassis modified to hold new components

12. Required Future Activities

This semester will conclude this team's work on the project. However, the following are important activities that need to be completed by future teams:

Done by installation in test lot:

- Complete cosmetic changes to the prototype chassis
- Waterproof front panel so that all openings are sealed
- Complete second round of testing
- Create administrator and supervisor user documentation

Other future activities:

- On-site testing
- Research efficiency and user friendliness
- Bug analysis and removal
- Document all code
- Create technical documentation for re-creation of the prototype
- Setup three computers as a system simulator for future testing and bug analysis
- Create final instruction manual
- Build second prototype system

13. Current Project and End-Product Status

The following is the current status of the project as of April 1st 2005.

- Master Component
    - Hardware is completely assembled
    - Debian Linux is installed
    - MySQL server is installed
    - Master / slave communication implemented
- Slave Component
    - Hardware
        - Hardware is completely assembled
        - Existing chassis modified
        - All input / output devices connected and working
    - Software
        - Main program written and tested
        - Classes written and tested
        - Utility functions written and tested
        - User input functions developed and tested
        - Windows XP Embedded is installed
        - First round of user testing completed
- System Chassis
    - Modified front to accept keypad, LCD, and printer
    - Base installed at prototype testing location near Armory on Iowa State University campus

14. Recommendation for Continued Effort

At this point in the project, the group recommends that development continue as originally envisioned while leaving the option for future expansion. In order to stay within time constraints, some non-critical features have been postponed. For instance, a future group will be needed to implement the upload of new system software via a laptop, or use of the ISU card as payment.

15. Documentation of Current Efforts and Results

This section of the Status Report details the group's current efforts and the results of such efforts.

Project Definition Activities

The project was already well defined prior to and no significant changes have been made in the current school session.

Research Activities

No significant research was conducted on this project this semester.

Design Activities

This semester has almost solely been focused on testing the prototype machine and updating the software based on any bugs found. More information about this aspect of the project can be found in a following section.

16. Implementation Activities

The parking meter system utilizes a client/server architecture, illustrated below and described in detail in this section. This semester, a great amount of progress was made in implementing both the server and client units.

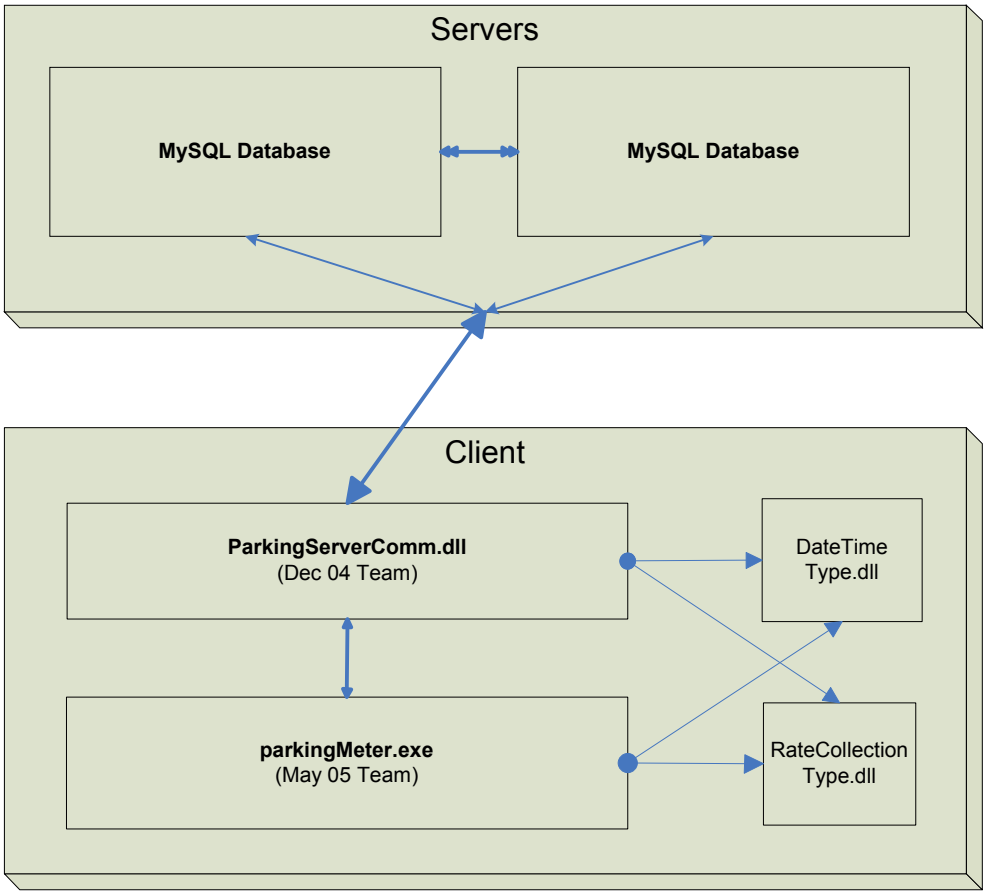


Figure 4 – System Block Diagram

Server

The server unit has been implemented using two embedded machines running the MySQL 1.4 database server on Debian Linux operating systems. The servers do not contain any application code written by the project team, but instead act only as data repositories for the client units. The servers contain a identical copies of a database called "parkinglot" that are kept consistent with each other using MySQL's built-in replication features. One server acts as a master server in this setup, providing all services to all clients while constantly sending records of data changes to the second server, the slave server.

Hardware

The servers were built using identical hardware configurations as described in the following figures.

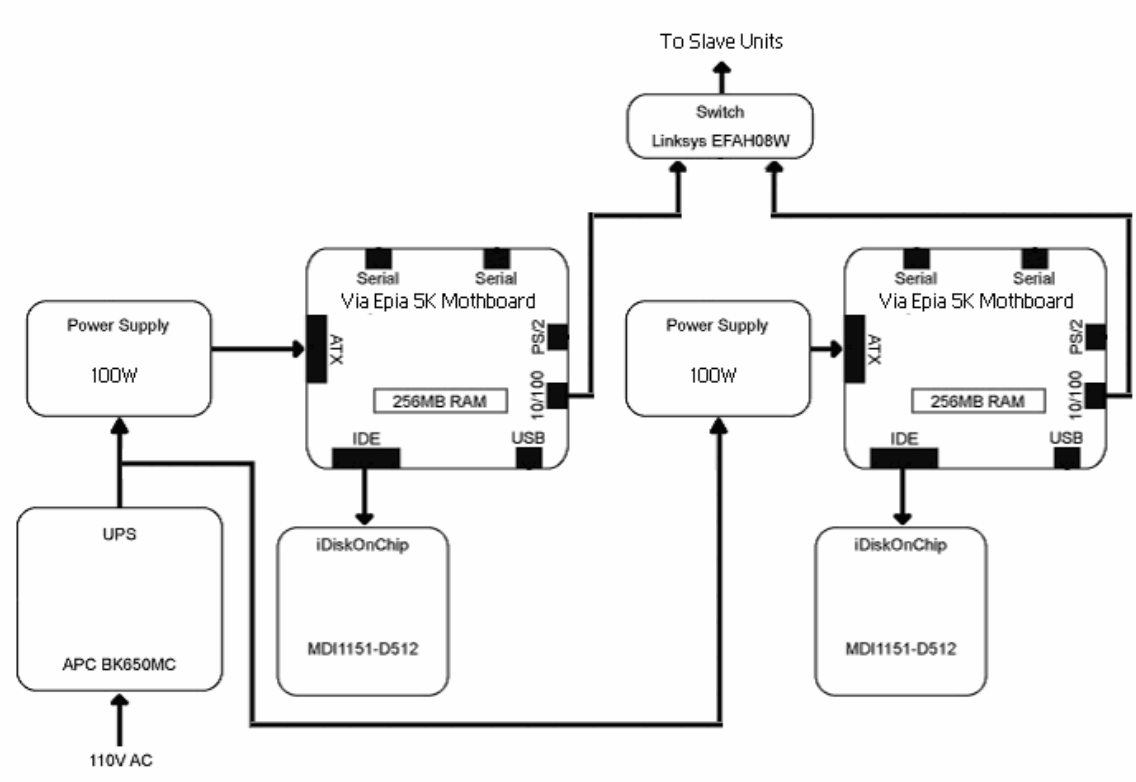


Figure 5 – Server unit hardware block diagram

Table 1 – Server unit hardware specifications and costs

Motherboard and Case (2 required)	SolarPC SB150
	• Via Epia 5K motherboard
	  ○ RJ-45 Network Jack
	  ○ Via C3 533 Processor
	• 100W power supply
	Source: http://solarpc.com
	Cost: $209.98 ea.

RAM (2 required)	256MB Ram • PC133 • 168 pin dimm Source:http://www.crucial.com Cost: $76.99
Network Switch	SMC EZ6508TX • 8 Port • 10/100 Mbs connectivity Source: http://newegg.com Cost: $34.00
Network Cables (4 required)	Generic • Cat5e • 100 Mbs bandwidth • 7 feet long Source: http://newegg.com Cost: $1.00 ea.
Solid State Memory (2 required)	Disk on Chip • 512 MB • IDE interface Source: M-systems Cost: $186.00

Failure Recovery

A freely available application for Linux called SuperMonkey allows for the seamless transition of services from the master to slave servers in the event that the master should fail. The master and slave servers are assigned IP addresses of 192.168.0.101 and 192.168.0.102, respectively. The IP address 192.168.0.100 is used to point to the one currently active server, which is the master (101) by default. Should the master fail, SuperMonkey will transfer the main IP (100) to the slave server (102). Client machines will be unaware of the change, since the data on the servers has been kept consistent by MySQL replication.

Database Structure

The database stored on each server stores information regarding the current expiration times on each stall in the lot, monetary transactions, a calendar for generating parking rate schedules, user login codes, and other statistical information. The database structure is detailed in the table below.

Table 2 -- Database Structure

Table	Field	Description
Calendar	**Contains date ranges of class sessions for determining rate schedule**	
	Id	Record ID number
	Periods	Text description of date range (e.g. fall_semester)
	Start	Starting date for period
	End	Ending date for period
	In_session	1: Classes in session, 0: Classes not in session
Holidays	**Contains holiday descriptions and dates**	
	Id	Record ID number
	Periods	Text description of holiday (e.g. Christmas)
	Dates	Date of holiday (e.g. 12/25/2005)
Login	**Login attempt log**	
	Id	Record ID number
	Logintime	Date and time of login attempt
	Failed	1: Login attempt failed, 0: Login attempt succeeded
	Name	Login code used in attempt
Lot_info	**Master and lot identification numbers**	
	Id	Record ID number (only one record in this table)
	MasterID	Designated ID for this master unit (e.g. 101)
	ParkingLotID	Designated ID for this parking lot (e.g. 60 for Lot 60)
Rates	**Rates and their effective times for parking in this lot**	
	Category	Category number for rate (see table below)
	Starttime	Time of day at which rate period begins
	Price	Dollars per hour rate for parking during period
RateStatistics	**Record of each transaction for statistics gathering**	
	ID	Record ID number
	Category	Category number for rate (see "Rate Categories" below)
	Hours	Number of hours paid for
	Date	Date and time of transaction
	TrackingID	Corresponding id number from "Tracking" table
	StallID	Stall number paid for
Special_events	**Dates of special events**	
	Id	Record ID number
	Start	Date and time that special event begins
	End	Date and time that special event ends
Stalls	**Expiration information for each stall in parking lot**	
	Id	Record id number

	Stall_number	Stall number
	Paid_until	Date and time until which stall is paid for
Tracking	**Transaction tracking information**	
	ID	Record ID number
	Stall_number	Stall number paid for
	Total_time	Time paid for in minutes
	Money	Money inserted into machine
	Slave_id	ID of slave machine customer used
	Date	Date and time of transaction

In order to keep track of statistical information on the lot, each category of rate period was assigned a number. Using integers rather than strings saves valuable storage space.

Table 3 – Rate Categories

Category	Description
11	In-Session Weekday Pre-Peak Shoulder
12	In-Session Weekday Peak
13	In-Session Weekday Post-Peak Shoulder
14	In-Session Weekday Off-Peak
15	In-Session Weekend
21	Out-of-Session Weekday
22	Out-of-Session Weekend
31	Holiday
32	Special Event

Client

The client unit has been completely implemented both in hardware and software. Block diagrams and specifications for each are detailed in this section.

Hardware

The hardware block diagram and specifications are listed in the figures below.

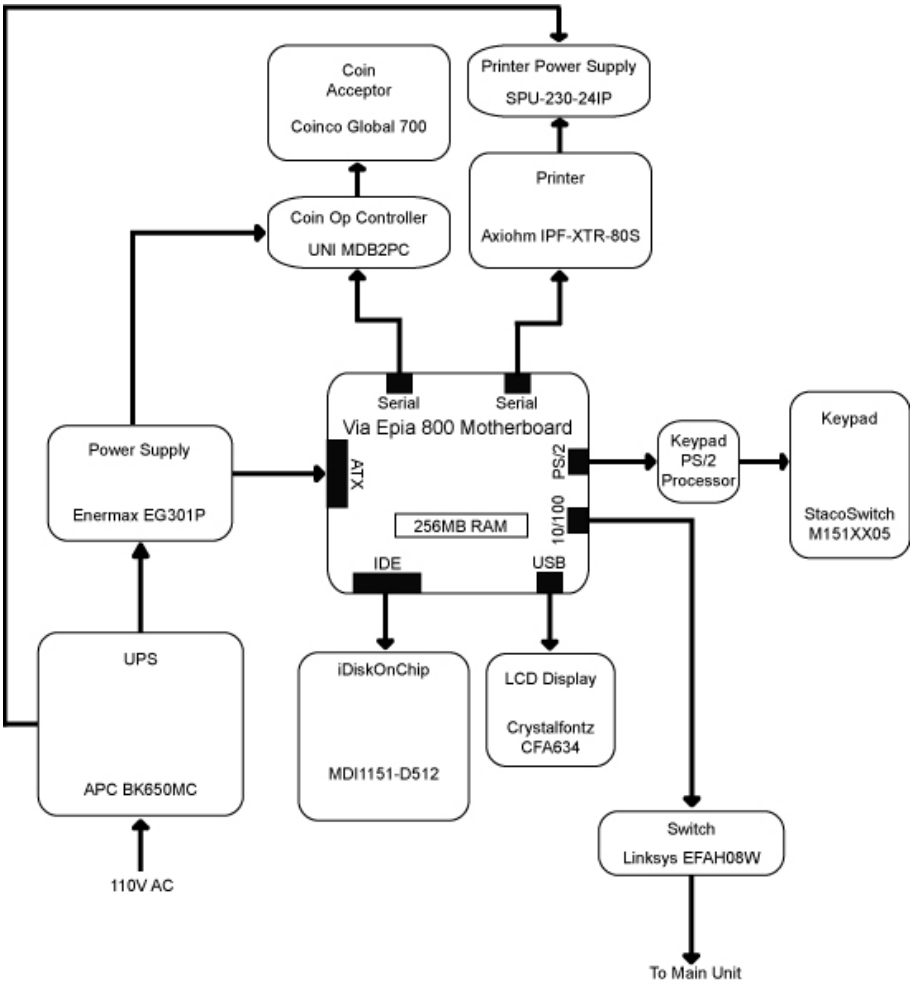


Figure 15 – Client Hardware Block Diagram

Table 4 – Server unit hardware specifications and costs

Motherboard	Via Epia 800 MHz motherboard • Via C3 800MHz Processor • USB Ports • 1 EPP/ECP Parallel Port • 1 16C550 Serial Port • PS/2 Ports

	Source: http://www.mini-box.com Cost: $150.00
Case and Power	Travla C158-90W Black • One PCI Expansion Slot • 90W power supply Source: http://www.caseoutlet.com Cost: $128.00
RAM	Crucial RAM • 512 MB PC133 Source: http://www.crucial.com Cost: $80.00
LCD Text Module	Matrix Orbital LCD4041 • 4x40 Character LCD • RS232 Serial Interface • LED Backlight Source: http://www.matrixorbital.com Cost: $118.00
Solid State Memory	M-Systems MDI1151-D512 512MBflash module • Solid state memory with IDE interface Source: http://www.tri-m.com Cost: $100.00
Keypad	StacoSwitch M151XX05 • 16-key • Rugged duty molded elastomer Source: http://www.stacoswitch.com Cost: $90.00
Keypad Processor	Motorola 6805 • Interface keypad to PS/2 port Source: Already procured (salvaged from old keyboard) Cost: $0
Coin Acceptor	Coinco Global 700 • MDB interface • Accepts nickels, dimes, and quarters Source: Iowa State DPS Cost: $0
Coin Acceptor Controller	Upstate Networks Incorporated MDB2PC • Serial interface to MDB protocol device

	Source: http://www.upstatenetworks.com/mdb Cost: $300.00
Printer	Fujitsu FTP-639MCL Thermal printer • 3" paper width • Serial RS232 interface Source: http://www.ipcprint.com Cost: approx. $350.00
Printer and Coin Acceptor Power Supply	Infinite Peripherals SPU-230-24IP • AC power in 24VDC power out Source: http://www.ipcprint.com Cost: $69.00
Battery Backup (UPS)	APC BK650MC • 650VA/400W Source: http://www.newegg.com Price: $100.00

Software

The client software has been completely implemented using the C++ language, and was developed in the Microsoft Visual Studio .NET 2003 integrated development environment. The software is currently undergoing a second round of system tests, which is detailed later in this document.

The client was implemented as a programmed state machine that runs certain routines based upon the state that it is in and then determines the next state based on user inputs. The basic structure is illustrated below. The most basic state is a simple menu in which the user is presented with several numbered options. The state machine loop awaits the users selection, which is accomplished by pressing a single number key, then uses information stored in the states collection to determine which state to go to next. More complex states call functions that perform tasks as complicated as prompting a user for a desired stall expiration time, calculating the cost of that amount of time, prompting the user for coins, calculating the time paid for, and then printing a receipt. Regardless of the complexity, the state machine handles the chore.

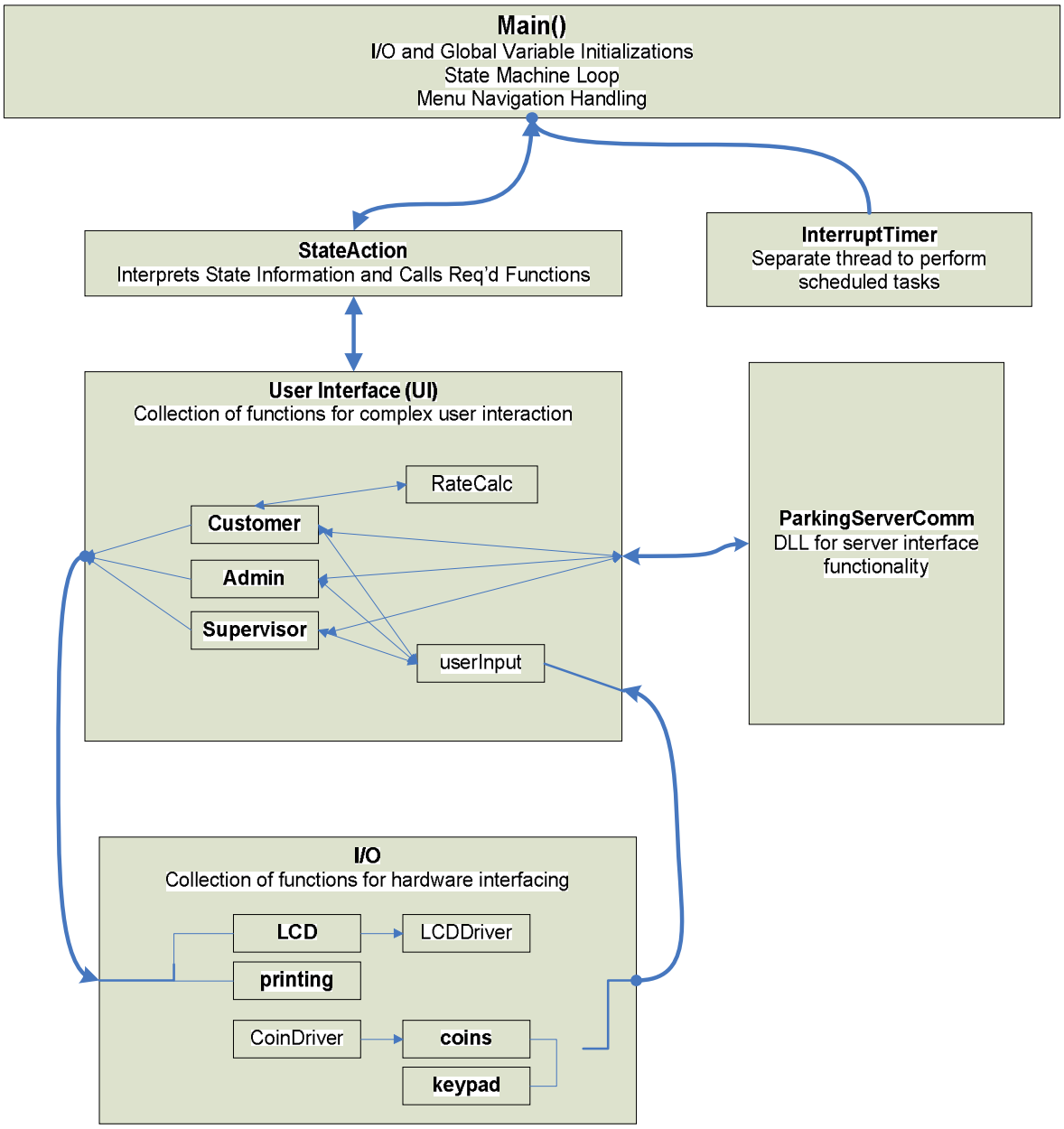


Figure 7 – Client Software Block Diagram

The main parkingMeter.exe application runs in a console window and coordinates several software modules together, including custom classes and modules for hardware I/O, user interaction, and other utility functions. These functions are described below.

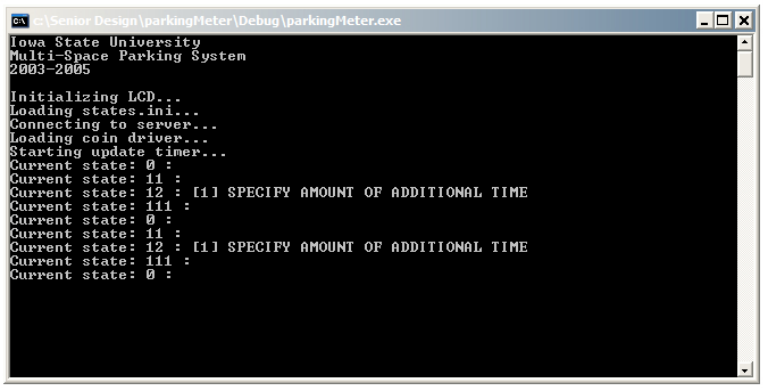


Figure 8 – parkingMeter.exe Screenshot

Client Software Module Hierarchy

Below is the hierarchy for the client software.

- **ParkingMeter.exe – Main Client Program**
  - parkingMeter.cpp – state machine loop
  - stateAction.cpp – calls helper functions based on current state
  - states.ini – initialization text file containing state information in a serialized form. The StateCollectionType class includes a member function for parsing this file into a series of StateType objects for use in the parkingMeter.cpp module
  - Custom Internal Classes
    - StateType.cpp – state information object
    - StateCollectionType.cpp – dynamic collection of state types object
  - Input and Output
    - CoinDriver.cpp – translates coin acceptor inputs into key presses (runs as a separate thread)
    - Coins.cpp – routines that prompt user for coin entry
    - Comport.cpp – freely available class for interacting with a serial port (used in CoinDriver.cpp)
    - IOenable.h – contains global constant indicating whether or not to load CoinDriver and LCDDriver
    - LCD.cpp – utility functions for displaying text to the LCD module
    - LCDDriver.cpp – hardware driver to display text on LCD module
    - Printing.cpp – utility functions for sending text to the printer
  - User Interface
    - Admin.cpp – state and utility functions for the administrator menu options
    - Customer.cpp – state and utility functions for customer menu options
    - RateCalc.cpp – utility functions for calculating the monetary amounts due for customers
    - Supervisor.cpp – state and utility functions for supervisor menu options

        - userInput.cpp – utility functions for getting complex user input (e.g. dates, times, other numbers)
    - Utilities
        - InterruptTimer.cpp – calls functions periodically for system updates and server-client time synchronization (runs as a separate thread)

- **DateTimeType.dll – Custom Date and Time Object (used by ParkingMeter, ParkingServerComm, and RateCollectionType classes)**
    - DateTimeType.cpp – contains all member and friend functions for the DateTimeType class
    - This class is a wrapper the ANSI C time.h

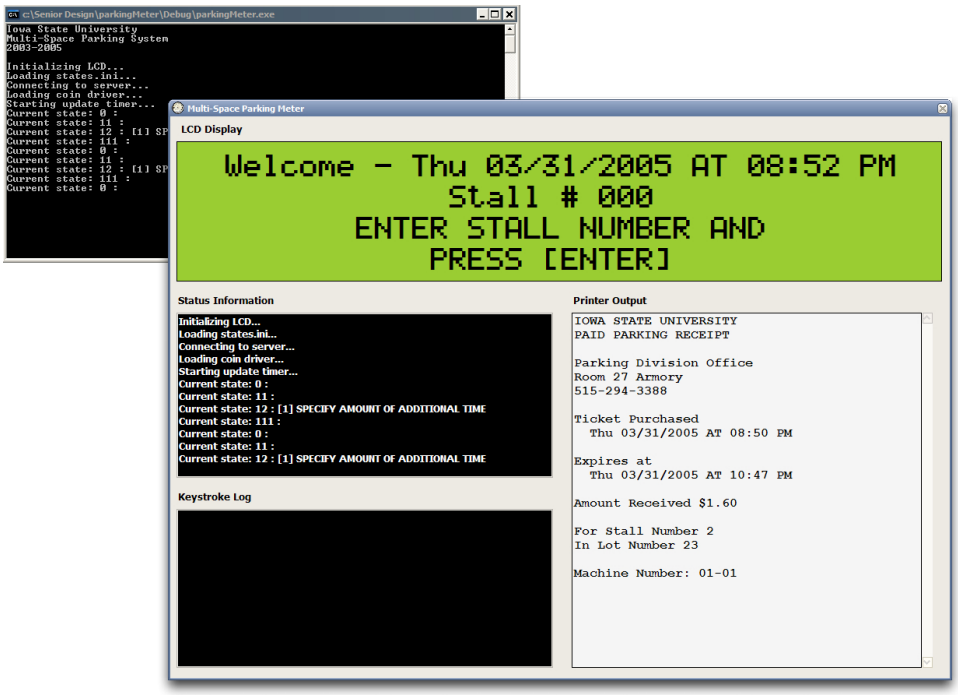
- **RateCollectionType.dll – Custom collection class for storing a rate schedule**
    - RateType.cpp – RateType object that stores information for each rate period in a rate schedule
    - RateCollectionType – dynamic collection of RateType objects

- **ParkingServerComm.dll – Routines for setting and retrieving data from the server unit (Developed primarily by the Dec04-02 team)**
    - MySQL++ - an open source API for interfacing C++ with a MySQL server (not developed by project team)
    - ParkingServerComm.cpp – utilizes MySQL++ to implement parking meter server interaction routines
        - all routines are implemented in a single file in order to access a global server connection object, but are categorized as follows
            - Authentication – functions for authenticating users for supervisory or administrative access
            - Calendar – functions for setting and retrieving calendar information
            - Rates – functions for setting and retrieving rate pricing and scheduling information
            - Stall – functions for getting and setting a stall's expiration time and for adding and removing stalls from the system
            - Statistics – functions for generating statistical reports for printing
            - User – functions for adding and removing user authentications
            - Utilities – functions fitting no other category

Simulator

In order to facilitate software development on the parking meter without necessarily using the actual server and client units, a hardware simulator was developed using Visual Basic .NET. VB.NET was chosen both for its familiarity to the project team leader and its ease of graphical user interface development. The program provides a simulated LCD character module of 4 lines by 40 characters, a simulated console for debugging outputs, and a simulated printer output spool. The simulator works by reading text files generated by parkingMeter.exe concurrently with LCD, printer, and console outputs. The executable is WinParking.exe and must be run in the same directory as parkingMeter.exe.

Figure 9 – Screenshot of User Interface



17. Testing and Modification Activities

Since the last version of this document, much testing has been done on the prototype unit. All of the hardware was hooked up and was confirmed to be working well together. After hardware testing, initial client interface testing began. This consisted of going through all of the states and ensuring that the menu options led to the proper "next menu" or state as described in the software functional document (SFD).

The first round of testing was completed in late February/early March so that program functionality specific bugs could be fixed as well as discover any bugs that may crash the program, causing it to become inoperable. These tests were the first to test both the server side of the software (or the database) with the client side and were designed to ensure that every function worked as described in the SFD. The test situations were developed by the Dec05-02 team and were distributed to each member of the Dec05-02 and May05-02 team in order to complete the testing in a timely manner. Figure 10 shows an example of one of the test situations.

Test Case – A-01

Functionality tested: Administrator mode login failure (Admin ID not on server)

Procedure: Press the up arrow key. Enter 3333333 on the keypad and press the enter key. Observe what is displayed.

Expected result: A. error message which states "INVALID ADMINISTRATOR LOGIN PLEASE TRY AGAIN OR PRESS 'CANCEL' TO QUIT" is displayed for 3 seconds, followed by a return to the welcome screen.
Actual result (P/F): P
Note:

Test Case – A-02

Functionality tested: Administrator mode login error (bad input)

Procedure: Press the up arrow key on the keypad twice. Observe what is displayed.

Expected result: An error message which states "YOU PRESSED AN INVALID KEY PLEASE TRY AGAIN OR PRESS 'CANCEL' TO QUIT" is displayed for 3 seconds, followed by a return to the welcome screen.
Actual result (P/F): F
Note: The message show up "Invalid Login Please Try again", then it goes back to the page "PLEASE ENTER USER CODE 0000000"

Figure 10 – Example of Test Cases

If a certain test fails for whatever reason (ranging from a program crash all the way down to a simple interface glitch) the failure is documented in the "Note:" section of the testing document with a detailed description of what exactly was wrong with the result of the test.

After each tester is done with their section of tests, they input any failures into a bug log—a spreadsheet used to simply track bugs and can be "checked off" when that bug has supposedly been fixed. Figure 11 shows an example of a portion of this log.

1	This sheet tracks test errors such as incorrectly testing a requirement, spelling errors, referencing incorrect figures, etc. These fixes should not require any other updating in most cases.										
2	Bug name	Bug ID	Current state	Date found	Found by:	Detailed explanation	Proposed solution	Date fixed	Fixed by:	Action taken	Files/test case #s e
3	Supervisor test cases	T-001	Fixed & closed	03/05/05	E.Sautter	In the non-session rate c	Note in step S-219 tha	03/28/05	D. Helvick	Changed 219 to S	Change non-session
4	Admin test step A-35	T-002	Fixed & closed	03/05/05	E.Sautter	The expected result sect	Change text in test ste	03/28/05	D. Helvick	Changed as sugg	Admin – A-35
5	Customer tests	T-003	Open	03/05/05	E.Sautter	Some errors were found i	Update customer tests as needed, marks have been made on the test documents and n				
6	Test Case S-205	T-004	Fixed & closed	03/05/05	B.Crist	Pressing '9' should send	Update S-205 to say: "	03/28/05	D. Helvick	Changed as sugg	Change calendar – S
7	Test Case S-207	T-005	Fixed & closed	03/05/05	B.Crist	Typo: after option 7 the te	Update S-207 to say: "	03/28/05	D. Helvick	Changed as sugg	Change calendar – S
8	Test Case S-229	T-006	Fixed & closed	03/05/05	B.Crist	Says to Enter 11/31/05 a	Change end date to 11	03/28/05	D. Helvick	Changed as sugg	Change calendar – S
9	Test Case S-246	T-007	Fixed & closed	03/05/05	B.Crist	Says to Enter 01/11/05 a	Fix either start or end d	03/28/05	D. Helvick	Changed 5/11/06	Change Calendar –
10	Test Case S-247	T-008	Fixed & closed	03/05/05	B.Crist	Says : dialog states "EN	Remove the word 'sem	03/28/05	D. Helvick	Changed as sugg	Change Calendar –
11	Test Case s-255	T-009	Fixed & closed	03/05/05	B.Crist	Says to enter 03/01/06 a	Change start or end so	03/28/05	D. Helvick	Changed 03/01/0	Change Calendar –
12	Test Case S-015	T-010	Fixed & closed	03/05/05	D.Helvick	Expected result is that th	Change documentation	03/28/05	D. Helvick	Changed as sugg	Paid-unpaid stalls –
13	Test Case S-018	T-011	Fixed & closed	03/05/05	D.Helvick	This is related to D-022.	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Paid-unpaid stalls –
14	Test Case S-019	T-012	Fixed & closed	03/05/05	D.Helvick	The text of the actual err	Fix the text in the test	03/28/05	D. Helvick	Changed as sugg	Paid-unpaid stalls –
15	Test Case S-024	T-013	Fixed & closed	03/05/05	D.Helvick	The print stalls menu sho	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Paid-unpaid stalls –
16	Test Case S-025	T-14	Fixed & closed	03/05/05	D.Helvick	This is related to D-023.	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Paid-unpaid stalls –
17	Test Case S-027	T-15	Fixed & closed	03/05/05	D.Helvick	This is related to D-024.	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Paid-unpaid stalls –
18	Test Case S-029	T-16	Fixed & closed	03/05/05	D.Helvick	This is related to D-025.	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Paid-unpaid stalls –
19	Test Case S-427	T-17	Fixed & closed	03/05/05	D.Helvick	There is no cursor, per se	Fix wording of expecte	03/28/05	D. Helvick	Added check for	Add-delete administ
20	Test Cases S-430, S-431	T-18	Fixed & closed	03/05/05	D.Helvick	The actual error message	Fix expected results to	03/28/05	D. Helvick	Changed as sugg	Add-delete administ
21	Test Case S-433	T-19	Fixed & closed	03/05/05	D.Helvick	The screen is not display	Fix expected result for	03/28/05	D. Helvick	Removed mentior	Add-delete administ
22	Test Case S-438	T-20	Fixed & closed	03/05/05	D.Helvick	There is no name field in	Delete test case.	03/28/05	D. Helvick	Deleted test case	Add-delete administ
23	Test Case S-442	T-21	Fixed & closed	03/05/05	D.Helvick	The text of the dialog is c	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Add-delete supervis
24	Test Case S-003 (all test files)	T-22	Fixed & closed	03/05/05	D.Helvick	There is no thank you me	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	All admin and super
25	Test Case S-445	T-23	Fixed & closed	03/05/05	D.Helvick	There is no cursor, per se	Fix wording of expecte	03/28/05	D. Helvick	Removed mentior	Add-delete supervis
26	Test Case S-453	T-24	Fixed & closed	03/05/05	D.Helvick	The text of the dialog is c	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Add-delete supervis
27	Test Case S-456	T-25	Fixed & closed	03/05/05	D.Helvick	There is no name field in	Delete test case.	03/28/05	D. Helvick	Deleted test case	Add-delete supervis
28	Test Case S-001 (all test files)	T-26	Fixed & closed	03/28/05	B.Crist	Returns to the login scre	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	All admin and super
29	Test Case S-002 (all test files)	T-27	Fixed & closed	03/28/05	B.Crist	The invalid login screen is	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	All admin and super
30	Test Case S-004 (all test files)	T-28	Fixed & closed	03/28/05	B.Crist	There is no system repro	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	All supervisor test fil
31	Test Case S-211	T-29	Fixed & closed	03/28/05	B.Crist	"DATE VALUES" should	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Change Calendar –
32	Test Case S-216	T-30	Fixed & closed	03/28/05	B.Crist	"MENU LEVEL" should b	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Change Calendar –
33	Test Cases S-217, S-218	T-31	Fixed & closed	03/28/05	B.Crist	Error text is different – se	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Change Calendar –
34	Test Case S-220	T-32	Fixed & closed	03/28/05	B.Crist	No "THE". "DATE VALUI	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Change Calendar –
35	Test Case S-229	T-33	Fixed & closed	03/28/05	B.Crist	No "SEMESTER". "DATE	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Change Calendar –
36	Test Case S-238	T-34	Fixed & closed	03/28/05	B.Crist	"DATE VALUES" should	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Change Calendar –
37	Test Case S-247	T-35	Fixed & closed	03/28/05	B.Crist	No "SEMESTER". "DATE	Fix expected result for	03/28/05	D. Helvick	Changed as sugg	Change Calendar –

Software / Documentation / Test

Figure 11 – Example of bug log

For each bug found on a given test, each member will have to record the bug name (which test case from which the bug came), the bug ID (to keep track of specific bugs) a detailed explanation indicating the specific problem, and a proposed solution to the bug in the spread sheet. (See Figure 12) When the bug is fixed, the person that fixed the bug will denote this along with the date that the bug was fixed.

The project teams have recently finished the first round of testing and have fixed most of the problems found thus far. A second round of testing has begun in order to further test the prototype and ensure that there are no bugs. This process will continue until all major bugs in the software are eliminated.

Following this, the prototype unit will be moved to a parking lot and tested outside with real customers and administrator/supervisors. Customers will have the opportunity to leave any feedback and/or suggestions for improvements to the design teams by filling out the form found in Appendix B. Administrators and supervisors will be able to directly contact the teams for support and suggestions.

18. Estimated Resources and Schedule

This section will provide an estimate of the resources required for the project and the project schedules. The effort that will be spent on the project has been divided into tasks as listed below.

- Task 1: Project Familiarization
- Task 2: Low-Level Slave Design
  - Subtask 2.1: User Interface Flowcharts
  - Subtask 2.2: Class and Function Descriptions
  - Subtask 2.3: Block Diagram
- Task 3: Slave Implementation and Unit Testing
  - Subtask 3.1: Class Implementation
  - Subtask 3.2: Function Implementation
  - Subtask 3.3: Main Function Implementation
  - Subtask 3.4: Hardware Implementation
- Task 4: System Integration
- Task 5: System Testing
- Task 6: Bug Analysis and Removal
- Task 7: Demonstration
- Task 8: Documentation, Literature

Table 5 – Personnel Effort Requirements (revised)														
Personal Effort (in hours)														
Name		Task 2			Task 3									**Total**
	Task 1	2.1	2.2	2.3	3.1	3.2	3.3	3.4	Task 4	Task 5	Task 6	Task 7	Task 8	
Christopher Dasch	10	4	11	9	9	38	35	5	36	0	65	5	8	**235**
Ted Kwan	8	3	7	7	7	41	27	2	0	17	0	5	12	**136**
Jesse Pink	18	9	4	6	3	15	30	8	2	18	0	5	37	**155**
Andrew Ross	0	0	0	0	0	0	0	0	0	13	0	5	15	**33**
Pete Stoltenow	14	11	7	6	6	30	35	15	20	14	0	5	10	**173**
Subtotal Hours	50	27	29	28	25	124	127	30	58	62	65	25	82	**732**
Total Hours	**50**	**84**			**306**				**58**	**62**	**65**	**25**	**82**	**732**

Table 6 – Other Resource Requirements		
Equipment and Other Resources		
Item	**Team Hours**	**Cost**
Motherboard/Processor 1	0	$150.00
RAM 1	0	$50.00
Storage 1	0	$200.00
Motherboard/Processor 2	0	$150.00
RAM 2	0	$50.00
Storage 2	0	$200.00
LCD	0	$75.00
Keypad	0	$100.00
Misc. Buttons	0	$50.00
Printer Controller	0	$120.00
Ethernet Switch	0	$57.00
UPS Battery Backup Unit	0	$100.00
Housing	0	$0.00
Project Poster	10	$50.00
TOTAL	10	$1,352.00

Table 7 -- Financial Requirements	
Item	**Cost**
Parts and materials	$150.00
Motherboard/Processor 1	$50.00
RAM 1	$200.00
Storage 1	$150.00
Motherboard/Processor 2	$50.00
RAM 2	$200.00
Storage 2	$75.00
LCD	$100.00
Keypad	$50.00
Misc. Buttons	$120.00
Printer Interface	$57.00
Ethernet Switch	$100.00
UPS Battery Backup Unit	$100.00
Housing	$0.00
Project Poster	$50.00
Services	
Shipping and handling	$50.00
Binding	$30.00
Equipment subtotal	$1,532.00
Labor ($10.75 / hour)	
Christopher Dasch	$2,053.25
Ted Kwan	$1,892.00
Jesse Pink	$1,978.00
Pete Stoltenow	$1,988.75
Previous Group Labor	$10,000.00 (estimate)
Labor subtotal	$17,912.00
TOTAL (With Labor)	$19,444.00

Schedule

Since May05-02 team has inherited this project from two previous teams, the schedule for this team starts in the later design phase. Some of the project deliverables will therefore be delivered in mid-implementation, though they may need to completed at an accelerated pace.

Included below is a Gantt chart describing the expected project schedule over the next two semesters, with a complete prototype built and tested by the end of the second semester.

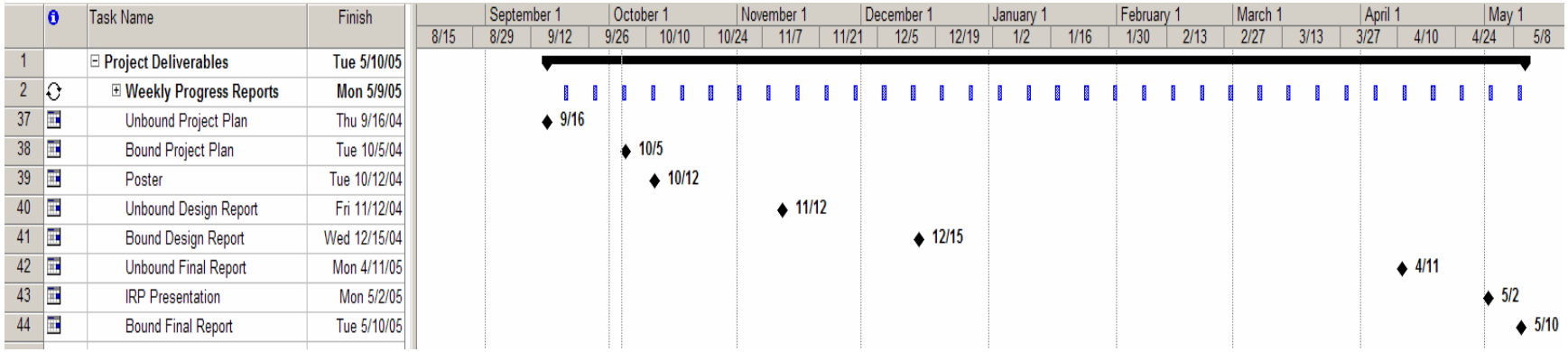
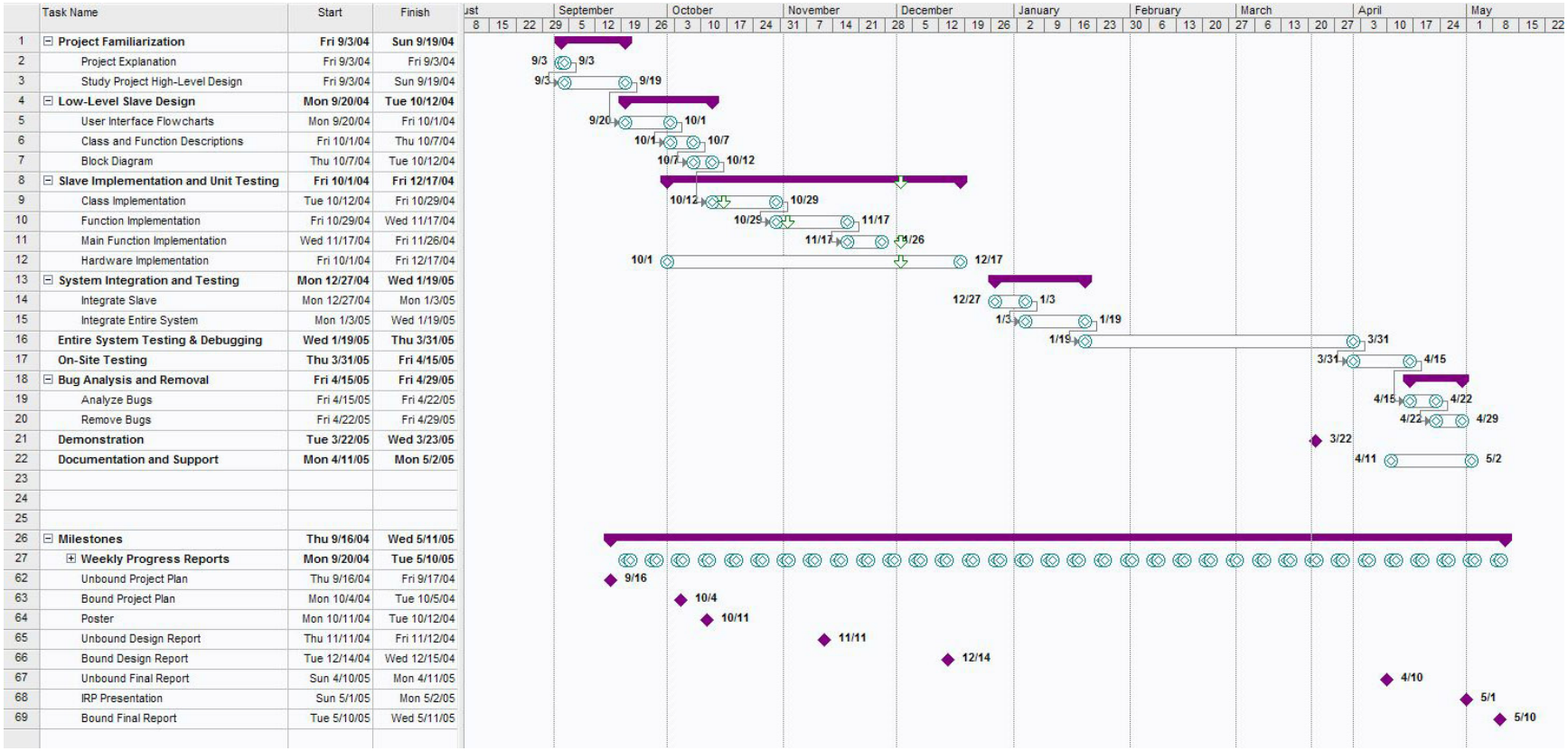


Figure 12 -- Gantt chart, Project deliverables



	Task Name	Start	Finish
1	**Project Familiarization**	**Fri 9/3/04**	**Sun 9/19/04**
2	Project Explanation	Fri 9/3/04	Fri 9/3/04
3	Study Project High-Level Design	Fri 9/3/04	Sun 9/19/04
4	**Low-Level Slave Design**	**Mon 9/20/04**	**Tue 10/12/04**
5	User Interface Flowcharts	Mon 9/20/04	Fri 10/1/04
6	Class and Function Descriptions	Fri 10/1/04	Thu 10/7/04
7	Block Diagram	Thu 10/7/04	Tue 10/12/04
8	**Slave Implementation and Unit Testing**	**Fri 10/1/04**	**Fri 12/17/04**
9	Class Implementation	Tue 10/12/04	Fri 10/29/04
10	Function Implementation	Fri 10/29/04	Wed 11/17/04
11	Main Function Implementation	Wed 11/17/04	Fri 11/26/04
12	Hardware Implementation	Fri 10/1/04	Fri 12/17/04
13	**System Integration and Testing**	**Mon 12/27/04**	**Wed 1/19/05**
14	Integrate Slave	Mon 12/27/04	Mon 1/3/05
15	Integrate Entire System	Mon 1/3/05	Wed 1/19/05
16	**Entire System Testing & Debugging**	**Wed 1/19/05**	**Thu 3/31/05**
17	**On-Site Testing**	**Thu 3/31/05**	**Fri 4/15/05**
18	**Bug Analysis and Removal**	**Fri 4/15/05**	**Fri 4/29/05**
19	Analyze Bugs	Fri 4/15/05	Fri 4/22/05
20	Remove Bugs	Fri 4/22/05	Fri 4/29/05
21	**Demonstration**	**Tue 3/22/05**	**Wed 3/23/05**
22	**Documentation and Support**	**Mon 4/11/05**	**Mon 5/2/05**
23			
24			
25			
26	**Milestones**	**Thu 9/16/04**	**Wed 5/11/05**
27	**Weekly Progress Reports**	**Mon 9/20/04**	**Tue 5/10/05**
62	Unbound Project Plan	Thu 9/16/04	Fri 9/17/04
63	Bound Project Plan	Mon 10/4/04	Tue 10/5/04
64	Poster	Mon 10/11/04	Tue 10/12/04
65	Unbound Design Report	Thu 11/11/04	Fri 11/12/04
66	Bound Design Report	Tue 12/14/04	Wed 12/15/04
67	Unbound Final Report	Sun 4/10/05	Mon 4/11/05
68	IRP Presentation	Sun 5/1/05	Mon 5/2/05
69	Bound Final Report	Tue 5/10/05	Wed 5/11/05

Figure 13 -- Gantt chart, Project tasks and subtasks

19. Lessons Learned

Successes

The project group learned how to successfully implement another team's design, and how to integrate our own design with theirs. The group also learned once completed, the project requirements and design should remain static. To attempt to change either one would push the project time table back, and the project would never be completed.

Challenges

Communication between project groups and members was a reoccurring problem. One group or member would have information that another one would need, and that information would not be shared. The group needs to make itself available at all times to other members, and respond to requests for information quickly.

Technical Knowledge gained

Due to this project, the group has successfully learned several pieces of software. These include Microsoft Project, Microsoft Visio, Microsoft Visual Studio .NET, Microsoft Windows XP Embedded and mySQL.

Non-technical Knowledge gained

The project group has learned about the importance of documentation on any project. Without proper documentation from the previous group, the group would not have gotten far. Also learned was the importance of attending project meetings. Meetings are not of much use if all members are not in attendance.

Possible changes if done again

If the project design could be done over again, the group would make a few changes. First of all more attention should have been paid to the previous team's (Dec0402) documentation. Often the group would have questions about the project that had already been answered in writing. Also, the project group is in the unique situation of designing and implementing the project in one semester, in order to combine the work with the other group. The group has learned that integration takes more time than one would have thought, and the group should schedule appropriately.

Also, documentation should be developed continually throughout the project. Many times the team found themselves writing documentation days and hours

before it was due to be complete, which lessened its quality and heightened stress on team members.

20. Risk and Risk Management

A number of potential risks have been identified:

Code integration

All code implementation will divide into several parts for each member. Even though the group will have a plan to go by, it is possible that compatibility problems may occur when putting the code together due to different format and variables. Moreover, different writing style may lower the code readability and affect the correction time. Deciding on the variables and styles that the group will be using ahead of time (before actually writing any code) will mitigate this risk. Also, any additional function or information must be reported to every member.

Equipment damage

Unintended damage to project hardware components will take a toll in both time and replacements costs. Properly handling and storing all equipment will mitigate this risk.

Equipment Availability

Essential hardware may not be available for some unforeseen reason. Many of the items used are produced in low volume and are not always readily available. This risk will be mitigated by thoroughly researching hardware selections. The hardware that has been chosen will most likely provide the type of requirements that the group need.

Loss of a Team Member

Should a team member leave the university or lose his life, the effect on the project should be minimal. Each team member will keep a detailed record of their efforts, so that their work can be continued by someone else.

21. Project team information

The following is all the contact information for the client, faculty advisors, and the team members working on the project.

Client

Doug Houghton
Captain
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31 Armory Building
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Fax: 515/294-0383
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Professor Ralph Patterson III
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Iowa State University
Ames, IA 50010
Vox: 515/294-2428
Fax: 515/294-6790
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Team Members

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Andrew Ross
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Peter Stoltenow
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515/441-0224
kwanted@iastate.edu

22. Closing Summary

Parking has become a growing problem with more and more automobiles on the road. In densely populated areas such as urban centers and corporate and academic campuses, the problem is only worse. As Iowa State works to cope with its parking predicament, it also needs a cost-effective solution to finance the construction and maintenance of new lots. Current multi-space pay-for-parking systems are too expensive and rigid to meet university needs, and old-style individual parking meters are inefficient for a large number of parking spaces. The parking meter system implemented in this project allows for easy and flexible administration of large parking areas, saving resources and consequently increasing revenue.

23. References

Prototype Parking Metering System – Phase 2: Design Document. – Dec 04-02, 6 April 2004
http://seniord.ece.iastate.edu/dec0402/Dec04-02%20Design%20Document.pdf

Software Functional Description. – Dec 04-02, J. Lamont & R. Patterson III, 19 July 2004

Appendix A
Parking Enforcement Officer Evaluation Form

Tester Name:_____ **Date Completed**:_____
Tester Phone #:_____ **Tester Email Address**:_____
Instructions:
The purpose of this test is to evaluate the use of this system to monitor and enforce parking lot payments. Before completing the survey below, complete the following tasks:
1) Print the list of paid and unpaid stalls for enforcement.
2) Empty the coin box and retrieve the auditing receipt.
3) Print the diagnostics report.

Please circle the number that best describes your response as follows:
1 – Very Poor 2 – Poor 3 – Indifferent 4 – Good 5 – Excellent

Were the instructions clear and easy to understand?	1	2	3	4	5
Was it clear and easy how to print the enforcement receipt?	1	2	3	4	5
Did the enforcement receipt have all of the information that you needed? If not, please comment on what info was missing.	1	2	3	4	5
Did the auditing receipt print when you opened the unit to empty the coin box?	1	2	3	4	5
Did the auditing receipt that printed when you opened the coin box have the information that you desired? If not, please comment on what info was missing.	1	2	3	4	5
Were you easily able to print a diagnostic report?	1	2	3	4	5
Did the diagnostic report contain all of the information that you thought was needed?	1	2	3	4	5
Were the key inputs easy to use?	1	2	3	4	5
Did the instructions clearly indicate which keys you were to press?	1	2	3	4	5
What is your overall impression of this machine	1	2	3	4	5

Please provide any additional comments or suggestions on the back of this form

Appendix B
Patron Evaluation Form

Tester Name:_____ **Date Completed**:_____
Tester Phone #:_____ **Tester Email Address**:_____

Instructions:
The purpose of this test is to evaluate the use of the parking meter. Before completing the survey below, please complete the following tasks:
1) Pay for a parking space by entering coins first and not by choosing the amount of time you would like to pay for.
2) Add time to the parking space by entering the time you would like to pay for and then depositing coins.
3) Complete the above transactions with and without printing a receipt.
5) Attempt to cancel the sale before you insert coins.

Please circle the number that best describes your response as follows:
1 – Very Poor 2 – Poor 3 – Indifferent 4 – Good 5 – Excellent

Were the instructions clear and easy to understand?	1	2	3	4	5
Was it clear and easy how to enter the stall number?	1	2	3	4	5
Was it clear and easy to enter the coins first and not choose the amount of time for payment?	1	2	3	4	5
Was it clear and easy to choose the amount of time to pay for and then insert coins?	1	2	3	4	5
Was it clear and easy to print a receipt?	1	2	3	4	5
Did the receipt have all of the information that you thought was necessary? If not, please comment on what was missing.	1	2	3	4	5
Were you able to cancel the transaction before depositing coins?	1	2	3	4	5
Were the key inputs easy to use?	1	2	3	4	5
Did the instructions clearly indicate which keys you were to press?	1	2	3	4	5
What is your overall impression of this machine	1	2	3	4	5

Please provide any additional comments or suggestions on the back of this form